Resting-State fMRI Signal Anti-Correlation Exists in Absence of Global Signal Regression

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Advanced MRI

Introduction

FMRI studies of spontaneous brain activity have shown anti-correlations between "task-negative" and "task-positive" regions (Fox et al. 2005). These anti-correlations could originate from

- Competing neuronal processes (Fox et al. 2009).
- The analysis procedure, specifically global signal regression (GSR) (Murphy et al. 2009; Saad et al. 2012).

Recent studies have demonstrated that such anti-correlations may occur only during short periods of time (Popa et al. 2009; Chang et al. 2010), inspiring us to further investigate the origin of anti-correlation. For this purpose, we used a novel temporal decomposition technique (Liu and Duyn, 2013).

Methods

Dataset and Preprocessing:

- 247 participants from the "1000 functional connectomes project" (FCP) (Biswal et al. 2010).
- Motion correction; Spatial smoothing (FWHM = 4 mm) and temporal filtering (0.005 - 0.1 Hz); Linear and quadratic temporal trends removal; Spatial co-registration to the MNI template; Nuisance regression of 6 motion parameters.
- With and without GSR: regressing out averaged signals from the white matter, CSF, and whole brain.
- Time series were standardized to Z scores.

Temporal Decomposition Procedure (Fig. 1):

- Select a 15% subset of time points showing highest signals at the posterior cingulate cortex (PCC).
- Classify and then average them into 8 groups based on their spatial similarity, resulting in 8 co-activation patterns (CAPs) (Liu and Duyn, 2013).

Results

- Simply averaging 15% of data selected (AvgMaps) almost perfectly replicates the default mode network (DMN) pattern derived with seed-based correlation analysis on the entire dataset (CorrMaps), with or without GSR (Fig. 2).
- The CAPs show various decompositions of the DMN that represent activity at distinct time points.
- The PCC-seeded correlation map using GSR shows strong negative values in a set of "task-positive" regions, and the CAPs decomposed from it, particularly those resembling the DMN pattern (CAP 1−4), also show negative values in these areas, suggesting that these regions tend to de-activate while the DMN nodes co-activate (Fig. 2, left column).
- Skipping the GSR procedure made the correlation map statistics shift towards positive values and left almost no areas with strong negative correlation, confirming findings from previous studies (Murphy et al. 2009; Saad et al. 2012).
- This effect, however, is not uniform across CAPs. CAPs 1−4 only show small shifts towards positive with CAP 2 showing almost no change at all; while CAPs 5, 6, and 8, which are related to visual and motor co-activations, demonstrate much larger shifts in their map statistics (Fig. 2, middle column).

Discussions/Conclusions

- The "task-positive" and "task-negative" regions show anti-phase activity at certain time points, even without GSR.
- Major effect of GSR is seen for CAPs of sensory-related areas, suggesting global signal increases occur when sensory regions are active, which may indicate intermittent periods of arousal or other neuronal processes that modulate sensory activity.
- Contribution of global neuronal processes to the fMRI signal is consistent with a previous primate study (Scholvinck et al. 2010).
- Anti-correlation between brain regions is not just an artifact caused by global signal regression but may be caused by brief periods of negatively correlated neuronal activity.

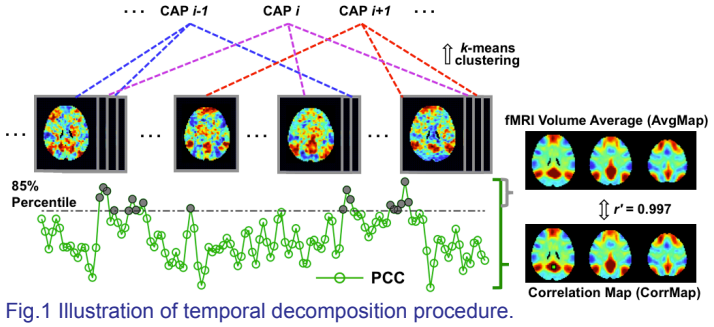

Fig.1 Illustration of temporal decomposition procedure.

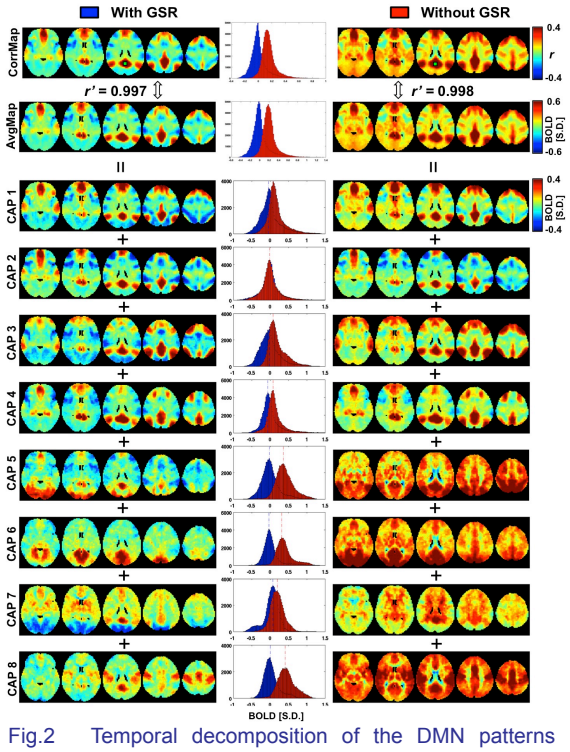

Fig.2 Temporal decomposition of the DMN patterns obtained with (left) and without (right) using GSR, and a comparison of map statistics distributions (middle).

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